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Analyzing the Chemical Abundances of Local Habitable Stellar Systems via NatCat

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Abstract

We present results from a compilation of abundance data for stars found within the Catalog of Nearby Habitable Systems, or HabCat (Turnbull & Tartar 2003). HabCat contains a listing of star systems which could conceivably host habitable planets based on the physical properties (such as stellar type, age, variability, iron abundances) of the star. Our focus has been on assembling abundance measurements for bio-essential elements – namely: C, N, O, Mg, S, Ti, as well as many others – for those stars in HabCat. We have created the first comprehensive catalog of abundances measurements for habitable stars within the solar neighborhood: the Nucleosynthetic Abundance Trends Catalog, or NatCat. We have mapped the spectroscopically determined abundances to find trends that occur both spatially and with regard to the evolution of the elements. We have also analyzed the maps with the locations of all known exoplanets overlayed on them. The element abundance maps from NatCat illustrate the nucleosynthetic patterns within 100pc of the Sun which may include potential hosts to Earthlike planets.

1. Introduction

The habitability of an exoplanet is strongly related to the physical properties of the host star. This is what determines the "habitable zone," or region surrounding a star at which a planet is able to reach and maintain a temperature conducive to life. The element abundances measured in the atmosphere of the host star also acts as a proxy for the abundances found within the planet. The composition of the planet is particularly important when determining if the planet is habitable because they provide the building blocks from which life may start. While there has recently been a slew of newly discovered exoplanets [1], the vast majority of them are "hot Jupiters," or large, gaseous planets orbiting very close to their host star, and are not favorable to carbon-based life. Therefore, we seek to find those places in our solar neighborhood that already possess bio-essential elements, such as C, N, O, Mg, S, Ti, in hopes of finding habitable, Earthlike exoplanets.

Turnbull & Tartar [3] examined the Hipparcos catalog in order to compile a catalog of purely habitable stars. Their major cuts were based on the luminosity and temperature of the star, leaving only certain main sequence F, G, K, and M-type stars. Stars were also excluded for large uncertainties in parallax, flux variations greater than five times solar, spectral energy output, stellar age indicators, and stellar metallicity ([Fe/H] only). The catalog in total currently contains 17,129 stars.

While HabCat contains a list of all those stars in the solar neighborhood that are potential hosts to habitable planets, the catalog has abundance measurements for only [Fe/H]. We have used HabCat as the foundation on which to build our new catalog, one that takes into account – not only the kinematics – but the chemical properties of the exoplanet which are so influential to habitability.

2. Compiling NatCat

We have compiled a catalog of stars found in HabCat with additional spectroscopic abundances from literature sources to create the Nucleosynthetic Abundance Trends Catalog (NatCat). The catalog currently consists of 41 element abundances for 891 unique stars within 100pc of the Sun, gathered from 43 literature sources and catalogs. Abundance values were not taken with the same instrument, measured using the same atmospheric model and atomic data, or analyzed with the same techniques between catalogs. We attempted to make the abundances more commensurate by placing all measurements on the same solar scale, namely, Lodders et al. (2009). This new catalog may allow us to explore our solar neighborhood more directly and efficiently when seeking out habitable planets.

3. Maps and Exoplanets

NatCat allows us to analyze the abundance patterns for a large number of elements in a large number of stars within the solar neighborhood. For example, we show an abundance plot for [Si/Fe] in Fig. 1, where each star is color-coded with respect to their radial distance from the Sun (see figure caption). This has been done similarly for the other 40 elements within NatCat. We have also analyzed the the abundances with respect to radial distance, vertical scale height within the disk, the direction toward or away from the galactic center, and galactic space velocity in both 2D and 3D.

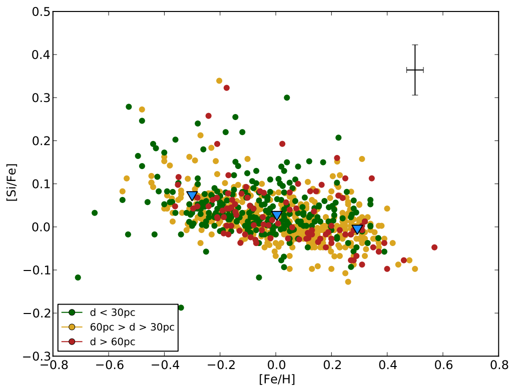

Figure 1: A 2D abundance plot for the most commonly measured element in NatCat, [Si/Fe] vs. [Fe/H], with a respective estimated errorbar in the top-right corner. The color-coded circles demarcate the radial distance, d (pc), of the star to the Sun. The blue triangles denote the data binned to show a more rigorous trendline, where the errors for each triangle are 1.2E-4 or smaller in both the x- and y-directions.

To date, ~500 extrasolar planets have been positively identified (Wright et al. 2011), with another ~1200 candidates recently observed by Kepler (Borucki et al. 2011). However, the vast majority of these exoplanets are not terrestrial, but "hot Jupiters", which may not be able to maintain carbon-based life. We have overlayed the location of these known exoplanets on our abundance maps. This enables us to match trends between our maps and the observations of the exoplanets to find those regions that are more biologically conducive. It may also allow observers to better coordinate the search for habitable, Earthlike planets more efficiently.

4. Summary and Conclusions

We have assembled the first comprehensive abundance catalog for habitable stars within 100pc of the Sun. NatCat allows us to examine the chemical evolution of 41 elements within 891 stars in order to find nucleosynethetic spatial trends within our solar neighborhood. When coupled with the locations of known exoplanets, our abundance maps enable us to determine those regions most conducive to finding terrestrial exoplanets containing bio-essential elements. They also serve as a framework on which observers may base future observations and satellite missions.

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References

[1] Borucki, W.J. et al: Characteristics of planetary candidates observed by Kepler, II: Analysis of the first four months of data, Astrophysical Journal, submitted, 2011

[2] Lodders, K. et al.: Group VI Astronomy and Astrophysics Numerical Data and Functional Relationships in Science and Technology Volume 4B: Solar System. Edited by J.E. Trumper, 2009

[3] Turnbull, M.C., & Tarter, J.C.: Target Selection for SETI. I. A Catalog of Nearby Habitable Stellar Systems, Astrophysical Journal, Vol. 145, pp. 181-198, 2003

[4] Wright, J.T. et al: The Exoplanet Orbit Database, Publications of the Astronomical Society of the Pacific, in press, 2011